Bureau Of Land and Water Quality
Division of Environmental Assessment
River Assessment Program
Standard Operating Procedure
Dissolved Oxygen and Temperature
Instantaneous Measurement using Electronic Meters

1. Applicability – This SOP should be followed for the collection of all data used by DEP for assessing the current state of water quality in river and streams. The data are used for developing water quality models and TMDL's, assessing the attainment status of water quality standards, and support for such programs as hydropower and waste discharge licensing.

2. Purpose – This procedure is used to determine the temperature and dissolved oxygen of rivers and streams as an instantaneous reading using an electronic meter.

3. Definitions

A. YSI. Yellow Springs International, manufacturer of dissolved oxygen meters commonly used by DEP staff.
B. Probe. Sensing device located at the end of a cable that is attached to the meter.
C. Calibration chamber - Small plastic bottle over end of probe or, built in chamber in body of meter designed for probe storage
D. O ring – Rubber rings that hold the membrane on the end of the probe.
E. Membrane – A clear, transparent and paper-thin substance similar to cellophane on the end of the probe. The membrane is permeable and allows gases such as oxygen to pass through into probe sensors while at the same time isolating most other undesirable sunstances.
F. KCl solution. Potassium Chloride solution used to fill the probe.
G. Calibration. Set of procedures established by the manufacturer to ensure that the meter is operating properly; a critical quality assurance step in meter preparation prior to use.
H. Profile. A series of readings taken from the water surface to the bottom usually in one meter depth increments.
I. Dissolved Oxygen Saturation Table – A table which gives the saturated dissolved oxygen concentrations (PPM) at given temperatures and air pressures
J. Project Manager – The project manager is a DEP employee who supervises, and has the highest decision making authority. In a DEP river study, an employee in DEA is the project manager. If data is being collected by the regulated community as licensed conditions, the license writer is the project manager.
K. Team Leader – Team Leaders have the highest authority within a sampling team.

4. Responsibilities

A. Appointing Team Leaders – It is the responsibility of the project manager to appoint team leaders in a DEP river study. Team leaders are chosen by the project manager based upon known competence, field experience, and familiarity with DEP methods. Team leaders could also be members of the regulated community being required to collect data as licensed conditions. In this situation leaders are not appointed by the DEP.

B. SOP Use - It is the responsibility of project managers to inform team leaders that this SOP must be used when collecting dissolved oxygen and temperature data with electronic meters for all applicable programs. Team leaders are responsible for assuring that the SOP is used by other team members collecting the data.
C. Recording of data - It is the responsibility of team leaders to assure that the data is correctly recorded on all sampling sheets.
D. Data Validation – The project manager has the responsibility of validating data, rejecting data, and making any adjustments to data. If a DEP license writer is project manager, data validation should be delegated to a employee in DEA. In DEP river studies, data sheets should be checked by the project manager at the end of each sampling run, unless this is impractical. For data collected outside the DEP, it is recommended that data initially collected be sent to DEP within 24 hours, if practical, for data validation. By following this recommendation, the undesirable consequence, for example, of having a whole summer's worth of data rejected can be avoided.
E. Volunteer and Other Monitoring – Data used by the DEP from volunteer monitoring groups or any other monitoring group (example - state or federal agency) collected outside the DEP must follow this SOP. It is the responsibility or the monitoring group to follow this SOP.

5. Guidelines and Procedures

A. Dissolved Oxygen Meter Preparation

1. Follow manufacturer's instructions for preparing D.O. meter for use.
2. The probe cable should be marked in one-meter increments. If using tape to do this, the tape should periodically be checked to assure the tape hasn't moved or some of the marks are missing.
3. Each meter should be equipped with a dissolved oxygen saturation table to assure proper meter calibration. Tables should be photocopied from the latest addition of Standard Methods.
4. Each meter should be equipped with the following items so that field repairs can be undertaken as necessary:
    - Extra KCL fluid and membranes for probe.
    - Extra " O " rings for probe.
    - Field record book/card for recording QA and repairs.
    - Scissors for trimming membrane.
    - Screw driver for removing back of meter to replace batteries.
    - Pencil with eraser.
5. The meter should be kept as dry as possible. Ideally the meter should be in water-resistant case with closed-cell padding to protect it from damage. Each meter should be equipped with a transparent plastic bag that should be used during rain events. The meter can still be operated within the plastic bag.
6. The meter should be turned on before leaving and traveling to the sampling location. If you forget to turn the meter on, keep in mind that the meter should be on for a minimum of 20 minutes before a reliable calibration can be achieved. If practical, also check meter probe (# see 7) at this time.

7. Remove probe from the calibration chamber and make sure the sponge is damp. If sponge is dry, wet the sponge and squeeze excess water. Check the membrane for air bubbles and wrinkles. If bubbles or wrinkles are present, remove membrane, refill with KCL solution and replace membrane (see Instruction Manual). Check to make sure no drops of water are clinging to the membrane and remove if present.
8. The meter should be checked for accuracy initially at the beginning of the sampling season and periodically throughout the summer. Temperature should be compared to a calibrated thermometer, and dissolved oxygen to a wrinkler titration or two other reliable meters. It is especially important to check meters in the lab prior to a large sampling event (i.e. three-day-intensive survey).
9. Replace meter batteries as necessary. Most meters are equipped with a low battery indicator that allow up to 50 hours of additional run time after low battery power is indicated.

B. Dissolved Oxygen Meter Calibration

1. Make sure that all steps necessary for meter preparation (see 5A) are employed.
2. Meter calibration is a necessary step that must be undertaken in all sampling to assure that dissolved oxygen readings are accurate.
3. If possible, the calibration should be undertaken at locations with stable environmental conditions, i.e. air temperature similar to water temperature. A shady area or indoor environment are ideal for this, but not always possible. In situations where the air temperature is more $5^{o}C$ greater than the water temperature, the probe calibration chamber can be placed in ambient water, being careful not to wet probe in this process. The probe can be wetted prior to calibration to hasten the cooling process.
4. If a barometer is available, use appropriate barometric pressure in the calibration process. If a barometer is not used, assume the appropriate level of oxygen for that temperature at 1 atmosphere (sea level or 760 mm. Hg).
5. Calibrate the meter assigned to your sampling team according to manufacturers instructions (YSI Instruction Manual). The saturated air method is used to calibrate all DEP electronic dissolved oxygen meters. Make sure there are no water droplets on probe membrane. The sponge in the calibration chamber should be damp, but not overly wet. (If sponge is too wet or dry, calibration won't be accurate.)
6. Recheck the calibration to assure temperature and dissolved oxygen readings have remained steady. If readings are not steady re-calibrate meter.
7. Crosscheck meters with other sampling teams (see E1) Re-calibrate if your meter does not agree well with other meters.
8. Calibration should be rechecked at the first sampling location and as necessary thereafter (usually every second or third sampling location). Each meter calibration check should be recorded on field sheet by entering the time of day and meter adjustment (= 0 if no adjustment). In situations when stable environmental conditions cannot be obtained, it is recommended to not calibrate in-between stations, but instead rely on calibrations before and after the sampling run, i.e. meter cross checks.

C. Dissolved Oxygen and Temperature Measurement

1. Meter calibration and proper meter preparation should be undertaken prior to measurement (see 5, a, b)
2. The calibration chamber should be removed just prior to submerging into the water for measurement and replaced after probe is removed from the water after measurement is completed.
3. After a meter has been turned on for use on a particular day, it should be left on until all sampling is completed for that given day.
4. Other relative information such as weather, samplers, meter #, and time of day at each location should be recorded on the sampling sheet in addition to the dissolved oxygen and temperature readings.
5. A desirable location for sampling along the width of a given transect is that location with the most current in shallow depth situations, or the most depth in quiescent situations. Eddies should be avoided as sampling locations.
6. Follow the Instruction Manual for operation of the meter for dissolved oxygen and temperature measurement. The manual explains that water movement of 1 ft/sec is needed across the probe membrane to obtain an accurate measurement of dissolved oxygen. This can be obtained by jigging of the probe and cable in a vigorous up and down motion. Jigging is not necessary if sampling in a strong current or if the meter and probe are equipped with a stirrer. (Without water movement, dissolved oxygen readings from the meter would be much lower than the actual dissolved oxygen.)
7. The probe should be submerged long enough at each measurement location until a stable reading occurs. The amount of time necessary for this will vary according to which meter is used (typically 15 seconds or slightly more).
8. If the sampling location has an overall depth of less than a meter, sampling is undertaken at mid depth. In locations exceeding a meter in depth, sampling should be undertaken in one-meter profiles starting at the water surface and ending at the last meter increment above the river bottom. In very deep situations, where it is known from prior experience that readings do not vary significantly vertically, profile increment greater than a meter (2 meters, typically) may be satisfactory.
9. If undertaking profile readings where there is significant depth, care should be employed to assure the cable is being lowered vertically and not scoping. In most situations, if sampling from a boat, anchoring of the boat is necessary to insure vertical measurement. The exception is where there are very strong currents such as tidal estuaries, where drifting is sometimes preferable to anchoring.
10. When sampling in marine waters, salinity corrections must be made to each dissolved oxygen reading. A meter with salinity compensation should be used for this. (If a meter with salinity compensation is not available, the corrections can be made after sampling is completed. This takes considerably more time.) The order for sampling parameters is as follows. Salinity readings are measured first and recorded on the sampling sheets. After recording the temperature on the field sheet, the salinity reading is then duplicated on meter salinity compensation knob. The dissolved oxygen reading can be recorded on the field sheet after switching the mode knob on the meter to this parameter.

D. Sample Location and Timing

1. Location - In river studies, the following factors determine the selection of sampling locations:
   - Maintaining adequate coverage
   - Accessibility
   - Control points (background)
   - Highly impacted locations where low dissolved oxygen is expected (i.e. above dams, below significant point source inputs)
   - Oxygen sources (tributaries, below dams with spillage, below waterfalls, end of long stretch of rapids)

2. Timing – Dissolved oxygen and temperature are usually taken twice per day; in the early AM to capture the lowest daily reading and in mid-afternoon to capture the highest daily reading. If data are to be used for assessing attainment status of dissolved oxygen criteria, at a minimum, the early morning data should be collected. The follow guidelines should be followed:
   - The AM data collection should begin at dawn as soon as there is enough light to safely sample. It is preferable to have all data collected before 8 AM. In some situations, this may not be possible. Data collected later than 9 AM may not be useable in attainment assessments.
   - The PM data should begin in early to mid-afternoon with the goal of trying to capture the maximum daily dissolved oxygen and temperature. It is usually not known when this occurs beforehand. As day-length shortens, the time of the maximum becomes earlier. As guideline sampling shouldn't start earlier than 1 PM and should be completed by 5 PM.

E. Quality Control

1. Cross-Checking of Meters - When undertaking multi team sampling efforts, meters of different sampling teams need to be cross-checked to assure consistency of data. All meters are cross-checked with water obtained in a sampling bucket before and after each sampling run. The dissolved oxygen and temperature within the bucket should be similar to ambient conditions that you will be sampling. In most studies, dissolved oxygen and temperature are taken twice a day, which requires three to four meter cross checks per day. The dissolved oxygen and temperature of all meters including the backup meters should be checked and should agree to within 0.3 ppm and 1.5^{o}C, respectively. If agreement cannot be achieved, meters should be re-calibrated and cross-checked again. Meters that can't reach agreement should be discarded until the proper repairs can be made (see troubleshooting, E4). The following procedure should be followed
   a. Before sampling
      - Calibrate all meters
      - Undertake cross-checks of dissolved oxygen and temperature in bucket
      - Record readings and time on QA sheet
      - Re-calibrate if QA objectives (see above) are not met
      - Cross-check and record readings again

- Use only those meters, which satisfy QA objectives

b. After completing a sampling run
   - Don't calibrate meters prior to cross-check
   - Undertake cross-checks of dissolved oxygen and temperature in bucket
   - Record readings and time on QA sheet*
   - Calibrate if QA objectives (see above) are not met
   - Cross-check and record readings again

   *This information is used to help validate data

2. Meter Requirements – It is preferable for each sampling team to have a backup meter available in the field, which can be employed in the event of failure of the primary meter. In any multi-team sampling effort, a minimum of one backup meter and three total meters are needed for any sampling effort. In a single team sampling effort, at least one backup (meter or Wrinkler) is needed to assure proper QC.
3. Suspect Readings – Dissolved oxygen or temperature readings that look unusual or are much different from other readings should be re-checked. When doing a profile, readings could be re-checked as you are raising the probe to the water surface. In a wide river, readings should be repeated in a different location along the transect to assure the location that you chose is typical of that given transect. The backup meter should also be used to verify unusual readings.
4. Duplicate sample stations are selected randomly in river studies. Coverage rates are typically 10%. In duplicate sampling, everything is repeated as an independent event. In a profile, all dissolved oxygen and temperature readings are repeated. Agreement should be to within the meter cross-check specifications (see D-1)
5. Meters should periodically be checked in the laboratory for accuracy (see A-8) Following the protocols for meter preparation and care should result in minimal operational problems.
6. Data validation – The following is used as guidelines:

A. Data Validated – Dissolved Oxygen, temperature,and salinity all meet QA objectives

B. Data Validated with Adjustments – Parameters fall outside QA objectives but still within 10% of objectives.

- Temperature – Determine if error is consistent (ie. 1^{o}C) or inconsistent (varies with temperature). Apply correction to temperature directly with the former and with a correction curve with the latter. Calibrate DO based upon corrected temperature. Temperature could be corrected after the fact but it should be noted on sample sheet if recorded temperature is corrected or uncorrected.
- Salinity- Apply corrected salinity to dissolved oxygen meter compensation knob.
- Dissolved oxygen – If correction results from temperature or salinity adjustments, determine the difference this makes in the saturated dissolved oxygen reading. The correction is the product of this reading and the dissolved oxygen % saturation. If the dissolved oxygen reading of a sampling teams fails to comply with QA objectives at the end of the sampling run before calibration, a straight line correction is normally made to their data, using the QA check information obtained at the beginning and end of the run.

C. Data Rejected – If any of the parameters are greater than 10% outside of QA objectives, the data for that particular parameter must be rejected. The data for the other two parameters may be acceptable, as long as any adjustments do not violate the 10% criteria.

F. Dissolved Oxygen Meter Care

1. Proper meter care is essential for accurate measurements.
2. Meters should be kept as dry as possible when being used in the field. When sampling is completed for a given day, the meter should be stored indoors in a dry place. The lid to the meter box should be opened during initial storage to facilitate drying. If very wet, remove meter and contents from storage box to facilitate drying.
3. The probe should be kept within the calibration chamber whenever it is not submerged in water for measurement to prevent excessive drying of the probe membrane.
4. Both the meter and the probe are very sensitive to shock. Avoid hitting the probe against such items as rocks, bridge abutments, the side of the boat, or the river bottom if in a cobble or rocky substrate. It is preferable to transport the meter within the cab of a truck rather than in the back of the truck where it can slide and be banged around and damaged.
5. Troubleshooting - If the meter does not calibrate or it readings do not satisfy QC objectives, the follow measures should be taken.
    a. Membrane – A faulty membrane is usually the problem. Change the membrane using directions in Instruction manual. The life of a membrane depends upon usage and sampling conditions, but 2 to 4 weeks is average.
    b. KCL Solution - If changing the membrane doesn't fix the problem, empty KCL solution within probe, flush out probe with distilled water, and replace with new KCL solution in addition to replacing the membrane. See Instruction Manual explaining how to replace fluid.
    c. Probe – The problem could be a faulty probe. Before replacing the probe, try swapping the probe of the faulty meter with the probe from a meter known to be in good working order. If this fixes the problem, the probe needs to be replaced. If not, then the probe is not the problem.
    d. Batteries / Corrosion – The batteries and their connections could be checked for corrosion. Replace batteries and clean any corrosion and recheck. Similarly all connections in probe and meter to cable should be checked for corrosion. Corrosion is a common problem if the meter is being used frequently in salt-water environments.
    e. Operating knobs – Corrosion here can also create problems. If you don't feel comfortable disassembling the electronic components of the knobs, send the meter out for repair.
    f. Repair – If all else fails, send the meter out to repair ASAP. Don't forget to notify others who may be using the meter, that it will be unavailable.

6. Winterizing – After you know use of the meter is completed for the field season, the following steps should be taken for long term storage.
    - Completely dry meter and case and all items in the case before storing.

- Remove batteries.
- Remove membrane and "O" ring.
- Remove KCL fluid including pumping diaphragm.
- Rinse entire probe chamber with distilled water.
- Cover top of probe with membrane to keep dust and dirt out for winter.
- Keep meter dry and in a heated storage place to prevent corrosion of
- electronic parts.
- Record winterization date and equipment repairs in Equipment Log.
- Label the meter and case as 'WINTERIZED' in an obvious manner (so
- users will know the current status of the unit).
  Now's the time to send the meter for repair if there are known pending problems, rather than waiting to do this during next year's field season.